



## Horse Dung and Soil Based Composites for Construction of Aesthetic Shelves in Rural Homes of Western Rajasthan

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### Abstract

Horse dung and clayey soil blended in presence of water are the base materials for aesthetic shelf construction. Women are the knowledge bearers of this construction technology. This technology is almost obsolete and requires revival. This paper details the materials, compositional features, process and techniques in the manufacture of this composite material. With curing and aging this composite gains compressive strength and is at par with the conventionally available cement products and which are environment friendly. It also implies substitution of this low cost composite material instead of cement products in construction. A novel method to manage horse dung as a resource is also enumerated.

**Keywords:** Aesthetic Construction; Compressive Strength; Horse Dung.

### 1. INTRODUCTION

Concrete is a common building material due its versatile properties and ease of availability (Savastano, 2009). Recently, cement was found to leave high carbon footprint compared to other natural materials (Worrell *et al.* 2001). In order to reduce cement usage citing environmental problem recycled industrial, agro and human waste are used as its substitute (Savastano *et al.* 2000). Substitution of regular construction material with locally available material, adopting low cost construction ways may help to reduce cost of construction, (Jin *et al.* 2015). They may alleviate effects of seismic forces (Arsene *et al.* 2003).

Corn cob powder based aggregates are being used for producing light weight concrete masonry structures (Faustino *et al.* 2015). Following the similar practice presently many developing countries where there is the possibility of producing cementitious composites from locally available material fulfill the need to explore new ways of producing robust building materials which cause CO<sub>2</sub> emission leads to global warming (Mustafa, 2015).

The utilization of traditional materials also helps to alleviate the pain of high energy expenditure for modern building construction (Satankar *et al.* 2017; Jin *et al.* 2015). The rural people focus on aesthetics in design more than engineering aspects of sustainability (Satankar *et al.* 2017). The durability of construction

materials for houses is also an important consideration. Only the problem of earth based construction is that it suffers is rapid decay due to climatic forces of precipitation, winds and temperature at a specific location and internal psychrometric parameter fluctuations due to moisture (Gouny *et al.* 2013).

The Fig. 1 shows the traditional formed walls to alleviate rainfall damage of the mud wall. The wall shown is aesthetically yet engineered with pathways in the shape of an inverted alphabet V. The inverted V allows the water to flow on hand impressed pathways and restrict flow only through the engineered pathways. These composites used in construction are also found to keep inside temperature cool during summer and warm during winters. The similar composites may also be adopted from traditional pottery making process, for example the recent innovation named G-filter for water filtration (Kaurwar *et al.* 2017, Soyam *et al.* 2016).

The women of Western Rajasthan learned this technology from their ancestors (Satankar *et al.* 2017). They also traditionally use thoroughly mixed composite made out of equal volumes of horse dung (HD) and local soil (meth mitti) to construct aesthetic, lightweight, cantilever shelves on the walls to store the crockery items and utensils of daily use (Satankar *et al.* 2017). They suggest this technique citing the composite materials medicinal properties to prevent the spread of microbial infection within the household (Satankar *et al.* 2017).

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**Fig. 1: Rural house with aesthetic wall of mud (Courtesy: Arna Jharna Museum, Rupayan Sansthan, Paota, Jodhpur, Rajasthan)**

This article elaborates the material characterization of horse dung (HD) which is used in the manufacture of the composite. The simple curing of the composite is studied with weight loss phenomenon with time. The compressive strength of the horse dung soil (HDS) composite is compared with other manmade engineering materials. The stress intensity (fracture toughness) property of HDS composite is also discussed.

## 2. SAMPLE PREPARATION

The raw materials for HDS include horse dung and meth mitti. HDS contains soil and horse dung in proportions by volume, viz. 30:70 (or 30–70), 40:60 (or 40–60), 50:50 (or 50-50) & 60:40 (or 60-40) respectively. Before mixing, the horse dung & Meth Mitti both were manually sieved using a fine mesh wire sieves (Satankar *et al.* 2017). The soil was soaked in sufficient quantity of water for 24 hours and then blended with powdered horse dung (Satankar *et al.* 2017). The resulting dough was then formed into a rectangular shape of size (250mm x 250mm x 20mm). The resulting shapes were exposed to open environment (temperature of 35 °C, humidity of 42% and stand still air conditions) for about 28days with regular observation on change in weather condition as well as change in weight and dimension (Satankar *et al.* 2017).

## 3. EXPERIMENTAL METHODOLOGY

### 3.1 Material Characterization

Samples of raw material of HDS i.e. horse dung and meth mitti were ground to powder to make them suitable for various characterization techniques. The

microstructural characteristics of raw material were identified using scanning electron microscopy (SEM) (EVO18 special edition Carl Zeiss).

### 3.2 Curing Test

HDS is kept under observation for change in its weight for a period of 28 days (Wilby, 1977). Each HDS sample was weighed at regular intervals using standard electronic weighing machine (Model Virgo, Danwer Scales, India) of accuracy 0.01g. The atmospheric temperature and humidity, were measured using a MEXTECH make meter (M288CTHW, MEXTECH, India).

### 3.3 Density Measurement

To analyze the effect of soil & horse dung (percent by volume) fraction on the strength characteristic on the composite the density were measured using classical formula for measurement of density, which is

$$\text{Density} = \frac{\text{Mass (Kg)}}{\text{Volume (m}^3\text{)}} \quad (1)$$

of varying compositions. All the measurement of weights was done using the same weight measurement device (Model Virgo, Danwer Scales, India).

### 3.4 Compression Test

The 28 day cured samples of different HDS compositions at different ages of size 50 mm x 25 mm x 12.5 mm underwent compression tests. These samples were tested on universal testing platform (Model EZ50 Lloyd instrument, Germany). A loading rate of 3.5 N/s was used (Satankar *et al.* 2017).

### 3.5 Fracture Toughness

Different composites of distinct HDS compositions were tested using Mode I fracture tests using single edge notched bend (SENB) specimens. The specimens were made and tested according to the guidelines given for test specimen preparation procedure in ASTM standard E399-81. These samples were tested on universal testing platform (Model EZ50 Lloyd instrument, Germany) at a 3N/s loading rate (Satankar *et al.* 2017).

## 4. RESULTS & DISCUSSIONS

### 4.1 Material Characterization

The SEM analysis of HD shown in Fig 2 indicates a calcium rich substance. The white flakes adhering on to a not so dark base are nano particles of calcium

carbonate (Satankar *et al.* 2017). Nanoparticles of  $\text{CaCO}_3$  adhered to cellulose content provides HD with characteristics of a biocement thus influencing strong fibrous network (Cho *et al.* 2016). An increase in HD would prevent HDS failures due to bending (K-tron, 2014). The presence of calcium carbonate will also influence surface finish and help decrement in surface energy of HDS composite (Satankar *et al.* 2017). This will also help in preparing strong manure cakes which may disintegrate slowly in soil.

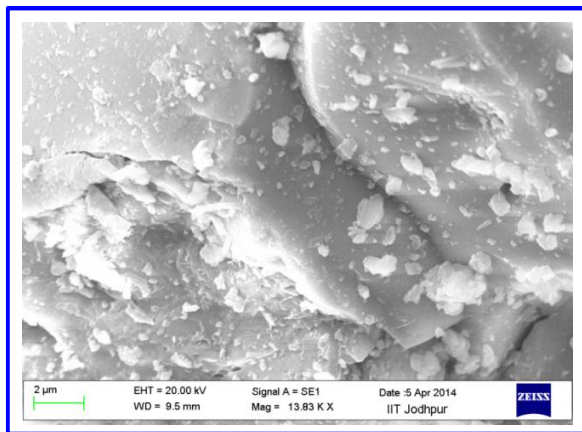


Fig. 2: SEM image showing white nano-flakes of calcium carbonate in the organic HD base

#### 4.2 HDS Curing Experiment Analysis

Weight loss gradient was found to be steep during first week for all HDS samples. This falling gradient is about 25-39%. Curing rate hence was considered to peak during the first week while it slowed down from second week onwards. The samples containing more volume fraction of HD comparatively weighed less.

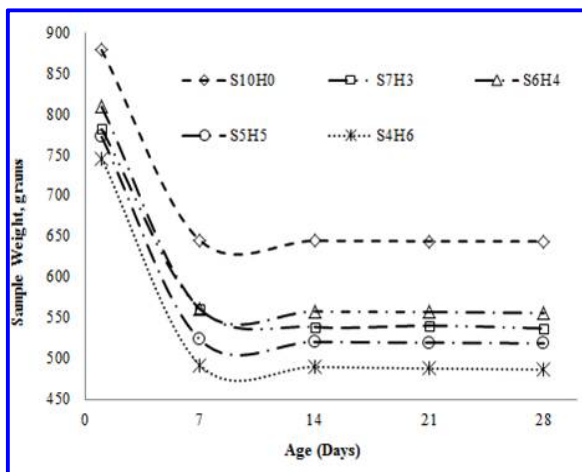


Fig. 3: Weight loss of HDS composite samples with time

#### 4.3 HDS Density Variation

Fig. 4 shows percentage change in HDS composite sample density at the age of 28. The samples with 50% HD reflect highest change in density among all other samples of distinct compositions. Low values of density of HDS composite are widely adopted in rural areas due their better heat conduction property during summer.

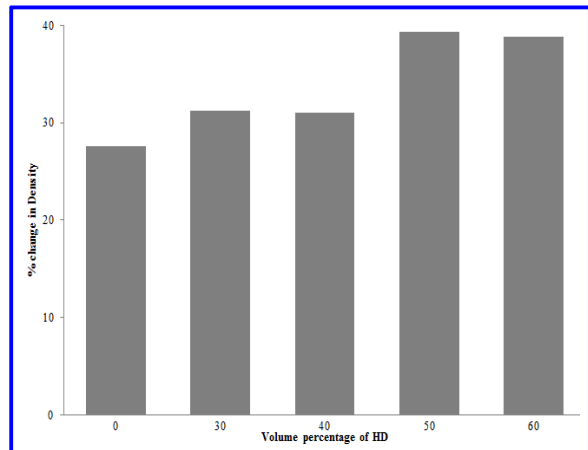


Fig. 4: % Change in density of HDS composite samples at the age of 28 days

#### 4.4 HDS Compressive Strength Analysis

The compression plot as a function of density for engineering materials in Fig. 5 illustrated a highly dense low compressive strength material. Compressive strength of the HDS composite varies from 0.7 Mpa to 2.1 Mpa. Density may vary from 1120 to 1980  $\text{kg/m}^3$  (Satankar *et al.* 2017).

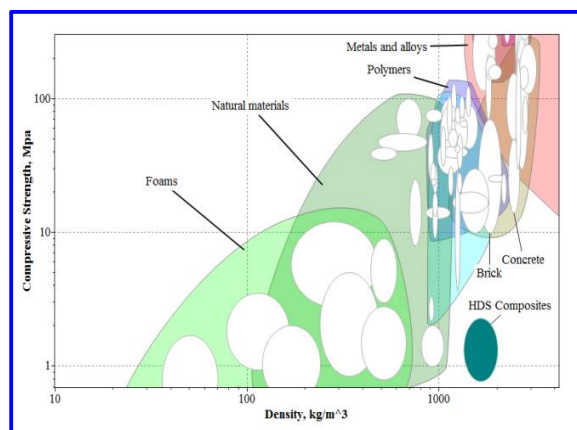


Fig. 5: Compressive strength as a function of density of HDS compared to other engineering materials (CES Edupack, Granta Design, IIT Jodhpur Licensed)

In the case of design of small cantilever shelves, the compressive strength does not play a pivotal role but tensile loading character is pertinent. The HDS due to its high density and low compressive strength can also be a novel material for slow release organic fertilizing solution.

#### 4.5 HDS Composite Fracture Toughness

Fractured surface roughness and trapping of cracks by fibers contribute to characteristics of toughening in these composites (Qiao, 2003). In the 50:50 HDS composites with uniformity in surface roughness is observed and hence may fare well against 40:60 and 60:40 HDS samples in toughness as is illustrated in Fig. 4 below. Due to no uniformity in the initial mix of the 70:30 HDS composite the fractured surface features large pits at some parts (Satankar et al. 2017). Therefore large fracture toughness is observed for 70:30 HDS composite in Fig. 6.

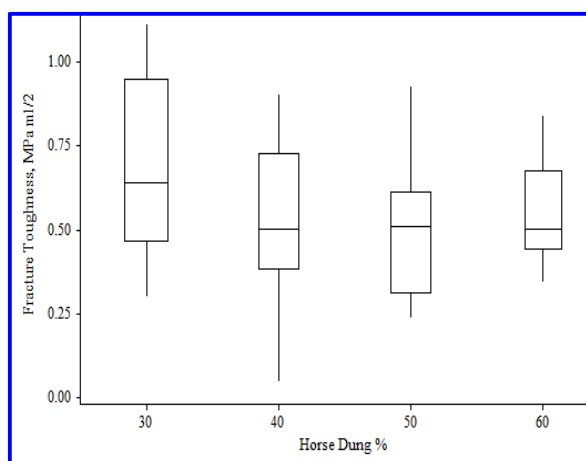


Fig. 6: Fracture Toughness of HDS with varying volume fractions of Horse Dung

#### 5. CONCLUSIONS

HDS is denser than foams and natural materials. These novel environment friendly materials are good in tensile properties but are low in compressive strength. This may help the material to disintegrate in moist environs. Therefore these materials are candidates for slow release fertilizing solutions which can be safely packed within local geo-textiles (Dave et al. 2017).

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